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Energy Aware Routing Protocol Based on Fuzzy Adaptive Transmission Range and Threshold Energy

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ABSTRACT

Energy efficiency is a major issue of concern in mobile ad hoc networks as mobile nodes rely on batteries, which are limited sources of power. In several environments, it is quite unwieldy task to replace or renew them. Energy is limited factor in case of ad-hoc networks. Several routing algorithms have been proposed to make routing energy efficient. A cross layer design approach is often used in designing energy efficient routing protocols. In this paper, a fuzzy based adaptive transmission range at MAC layer and fuzzy threshold based power aware routing at network layer is used to design a cross layer energy efficient routing protocol implemented for ad-hoc on-demand distance vector routing protocol (AODV). The results are compared with energy-efficient routing protocol based on adaptive transmission rage and fuzzy threshold energy (ATRAODV) based routing protocol which is implemented for AODV. It is observed that the proposed protocol performs better as compared to the ATRAODV in terms of energy consumption and network lifetime..

Key words : MANET, Energy, Network lifetime, Fuzzy, Threshold, Transmission range.

1. INTRODUCTION

Routing protocols developed for ad hoc networks have been classified into two main categories Proactive (table-driven) protocols, Reactive (on-demand) protocols and Hybrid routing protocol. In a proactive routing protocol, nodes periodically exchange routing information with other nodes in an attempt to have each node always know a current route to all destinations. In a reactive protocol, nodes exchange routing information only when needed, with a node attempting to discover a route to some destination only when it has a packet to send to that destination. Ad hoc network routing protocols that are hybrid have combination of table-driven and on-demand mechanisms.

1.1 Ad-Hoc On-demand Distance Vector Routing Protocol (AODV)

The Ad- hoc on demand Distance Vector (AODV) routing protocol uses Hello beacon for connectivity among the nodes. The AODV uses routing table to avoid loop and to distinguish between stale and fresh route. The routing table contains the sequence number and next hop information. If source has data to send, it floods the RREQ packet. The destination sends RREP packet in response to the request. If the link breaks then the intermediate node sends RERR (route error) message to the source node for information about the broken link. The AODV protocol uses the route discovery process as in DSR and routing table as in DSDV.
The AODV routing protocol is able to route the packet in a shortest route between source and destination. It does not consider the residual energy of the intermediate nodes while performing routing. Several algorithms have been proposed in literature to make this algorithm energy efficient either by controlling the transmission power of nodes and/or by performing power-aware routing.

2. LITERATURE SURVEY

A new energy aware routing (EAR) scheme which uses variable transmission range is discussed in [1]. The protocol has been incorporated along with the route discovery procedure of AODV as a case study. Variable transmission range is achieved by controlling the power level for each packet in a distributed manner at each node, thus affecting energy consumption of the network. The EAR protocol is able extend the network lifetime by 20% as compared to AODV routing protocol. Dynamic transmission power assignment for energy conservation routing (DPAECR) in MANETs has been proposed in [2]. The DPAECR updates the transmission power for every packet transmission. For the purpose of energy conservation, each node can dynamically adjust its transmitting power based on the distance of the receiving nodes. A more accurate analytical model to track the energy consumptions due to various factors, and a simple energy-efficient routing scheme, progressive energy efficient routing (PEER) to improve the performance during path discovery and in mobility scenarios is proposed in [3].
A new routing algorithm, called Local Energy Aware Routing (LEAR), which achieves a trade-off between balanced energy consumption and shortest routing delay, and at the same time avoids the blocking and route cache problems is proposed in [4]. A novel approach to modify route request broadcast based on node caching is proposed in [5]. The intuition behind node caching is that the nodes involved in recent data packet forwarding have more reliable information about its neighbors and have better locations (e.g., on the intersection of several data routes) than other nodes. Nodes which are

recently involved in data packet forwarding are cached, and used to forward route a request which makes the protocol more energy efficient. The energy issues related to routing in mobile ad-hoc networks such as network lifetime, energy metrics etc. are discussed in [6]. A scheme to control the transmission power of a node according to the distance between the nodes has been presented in [7]. It also includes energy information on route request packet and selects the energy efficient path to route data packets. An energy based ad-hoc on-demand routing algorithm that balances energy among nodes so that a minimum energy level is maintained among nodes and the life of network is increased is discussed in [8]. Minimum energy threshold limit is set for a mobile node, when a node reaches this threshold limit, it goes to sleep mode. This makes the nodes to conserve their energy and extend the lifetime of the MANET. The energy-aware routing in MANETs based on adaptive transmission range and fuzzy adaptive threshold energy is proposed in [9].

In this paper, the AODV routing protocol is modified to make it energy efficient based on fuzzy adaptive transmission range and threshold energy.

3. PROPOSED METHODOLOGY.

3.1. Energy efficient AODV routing protocol based on fuzzy adaptive transmission range and threshold energy.

When a node's radio transmission power is controllable, its direct communication range as well as the number of its immediate neighbors is also adjustable. While stronger transmission power increases the transmission range and reduces the hop count to the destination, weaker transmission power makes the topology sparse which may result in network partitioning. The transmission power control approach is not only energy efficient, but it also reduces the interference in the transmission ranges of the different nodes, which certainly leads to increase in the throughput of the network. In this paper, the objective is to propose a new fuzzy based adaptive transmission power control based on the number of neighboring nodes. It also incorporates load balancing by using adaptive fuzzy based threshold energy (AFTE) technique [10]. Thus, the proposed protocol is a cross layer design technique with fuzzy adaptive transmission power control at MAC layer and fuzzy adaptive power aware routing at network layer. The power control approach consists of fuzzification of the transmission range of a node depending on the number of neighboring nodes to ensure network connectivity. The default transmission range is usually 250 mts. The required transmission power (Pt) for a given transmission range (d) is determined by the Eq. (1).

$$Pt = \frac{Pr*d^4*L}{Gt*Gr*(ht^2*hr^2)} \qquad (1)$$

where, Pr is the receiver threshold power, d is the distance (transmission range), L is the system loss, Gt and Gr are transmitter and receiver gains (usually 1.0), ht and hr are the heights of transmitter and receiver (usually 1.5 mts), respectively.

The proposed method, which combines the fuzzy adaptive transmission power control and the adaptive fuzzy threshold energy routing, is as given below:

Procedure *Energy efficient AODV based on fuzzy adaptive transmission range and threshold energy*.

1. Let N_0 be the total number of nodes. Set the source node as the current node. Set the transmission power of the current node such that the transmission range *d* is 50 mts. (using Eq.(1))
2. Determine the number N_c of neighbors of the current node.
3. Determine the transmission range for the current node using procedure *fuzzy adaptive transmission range* (N_0, N_c) then select the next node using *adaptive fuzzy threshold energy* routing method and set the selected next node as the current node;
   if the current node is the destination node,
   then go to step 4,
   else go to step 2;
4. Stop.

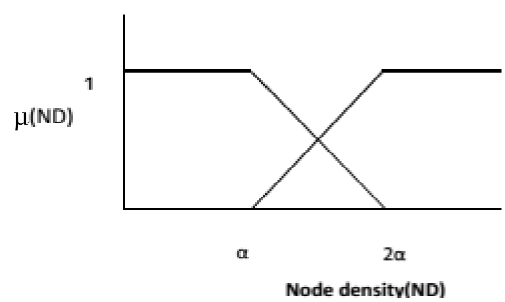


Figure. 1. Membership Functions for Different Node Densities

Procedure *Fuzzy Adaptive Transmission Range(* N_0 , N_c *)*

The membership functions μ_{low} and μ_{high} are given below (Figure. 1)

$$\mu_{low}(N_c) = \begin{cases} 1 & , N_c <= \alpha \cdot N_0 \\ \dfrac{N_c - 2\alpha \cdot N_0}{\alpha \cdot N_0 - 2\alpha \cdot N_0} & , \alpha \cdot N_0 <= N_c <= 2\alpha \cdot N_0 \\ 0 & , N_c >= 2\alpha \cdot N_0 \end{cases}$$

Where α is the percentage of total number of nodes that are neighboring nodes of the current node.

$$\mu_{high}(N_c) = (1 - \mu_{low}(N_c))$$

$$\mu_{TR}(N_c) = \max\left\{\mu_{low}(N_c), \mu_{high}(N_c)\right\}$$

Fuzzy decision is made as follows:

$$\mu_{TR}(Incr.by.50) = \mu_{low}(N_c)$$

$$\mu_{TR}(No.Chage) = \mu_{high}(N_c)$$

We compute,

$$\mu_{decision}(N_c) = \mu_{TR}(N_c)$$

Defuzzification:

If $\mu_{TR}(N_c) = \mu_{low}(N_c)$, then, decision is to increase transmission range by 50m.

$\mu_{TR}(N_c) = \mu_{high}(N_c)$, then, decision is no change in transmission range.

Procedure *Adaptive fuzzy threshold energy*:

Let RE_i, i = 1,2, …… , n , be the residual energies of the n neighboring nodes of a source node. Let minRE = min{ RE_i } , maxRE = max { RE_i } and midRE = (minRE + maxRE) / 2. We define the three fuzzy subsets of these nodes with low, medium and high residual energy whose membership functions μ_{low} , μ_{medium} and μ_{high} , respectively, are given below (Fig. 3).

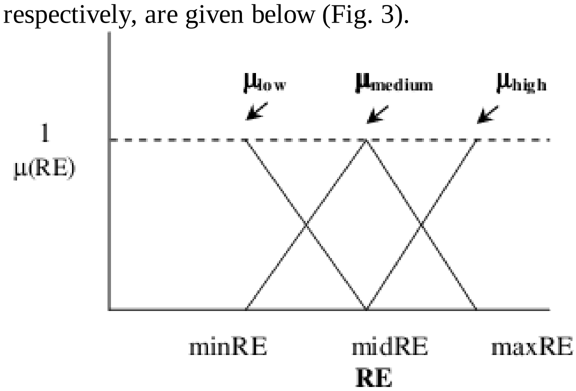


Figure. 2. Membership Functions for Nodes with Fuzzy RE Levels

$$\mu_{low}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{min\,RE - midRE}, & min\,RE \le RE_i \le max\,RE \\ 0, & midRE \le RE_i \le max\,RE \end{cases}$$

$$\mu_{medium}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{min\,RE - midRE}, & min\,RE \le RE_i \le midRE \\ \dfrac{RE_i - max\,RE}{midRE - max\,RE}, & midRE \le RE_i \le max\,RE \end{cases}$$

$$\mu_{high}(RE_i) = \begin{cases} 0, & min\,RE \le RE_i \le midRE \\ \dfrac{RE_i - midRE}{max\,RE - midRE}, & midRE \le RE_i \le max\,RE \end{cases}$$

Then, the membership value μ of RE_i for the i^{th} node is given by:

$$\mu_i(RE_i) = \max\left\{\mu_{low}(RE_i), \mu_{medium}(RE_i), \mu_{high}(RE_i)\right\}$$

Let RE_{TH} be the value of RE_i for which the membership value is minimum among neighboring nodes, i.e,

$$\mu_{Th}(RE_{TH}) = \min_{1 \le i \le n}\left\{\mu_i(RE_i)\right\}$$

If there is a tie, it is broken by selecting the node with min RE among the nodes with the same minimum membership value. Then, RE_{TH} obtained by this defuzzification process, is used as the threshold energy value, which is transmitted in RREQ packet to the neighboring nodes. If the residual energy of the intermediate node is greater than or equal to RE_{TH}, it is selected as the next node.

4. RESULTS AND DISCUSSIONS

The proposed protocols, namely, fuzzy adaptive transmission range and threshold energy is implemented for AODV and LAR routing protocols using NS2 simulator, for different simulation times (50,100,.., 500), and for different number of nodes (50,100,…, 300). The other parameters used for simulation are given below in Table 1. The simulation results for 50,150 and 250 nodes are shown below in Fig.3–4. The complete simulation results are given in Table II. The results of the proposed protocol is compared with ATRFTE protocol in terms of average energy consumed and network lifetime.

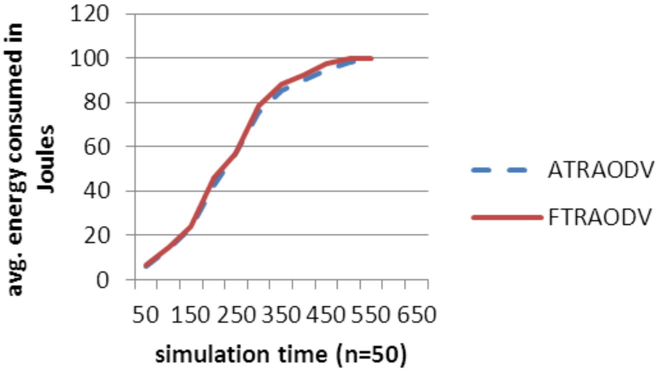
Table 1. Simulation Parameters

Parameter	Value
Simulation Time	50 … 500 sec.
Terrain Area	500 X 500 sq. mts
Number of Nodes	50…300
Node placement	Random
Propagation Model	RWP
Channel Frequency	2.4 G.Hz.
Routing Protocol	ATRAODV, FTRAODV
Transmission Range	Fuzzy adaptive
Initial Energy for each node	100 Joules

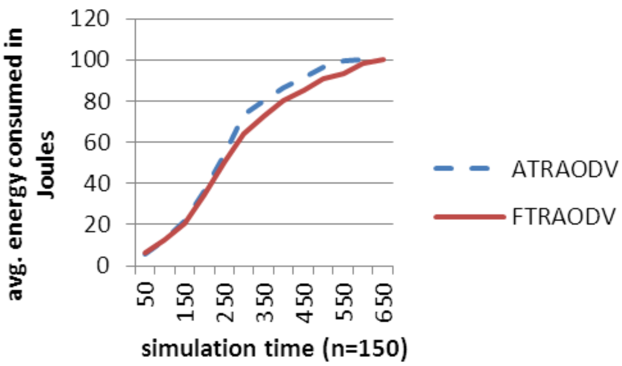
From the Fig. 3, it is observed that as the simulation time increases, the average energy consumed by the mobile nodes keeps on increasing. The proposed algorithm FTRAODV consumes less energy as compared to ATRAODV. All the nodes drain off their energy by 550 sec. for ATRAODV. But for FTRAODV all the nodes drain off their energy by 600-650 sec. From the figure it can also be seen that energy drain rate for FTRAODV is more gradual as compared to ATRAODV.

The Figure. 4 shows the percentage of dead nodes as the simulation time increases from 50 to 600 in steps of 50. It can be seen that the FTRAODV is able to attain more network life time as compared to ATRAODV routing protocol. The

FTRAODV protocol achieves almost same network lifetime for lower node density and 15% to 18% more network lifetime for higher node density, as compared to ATRAODV.



(a)



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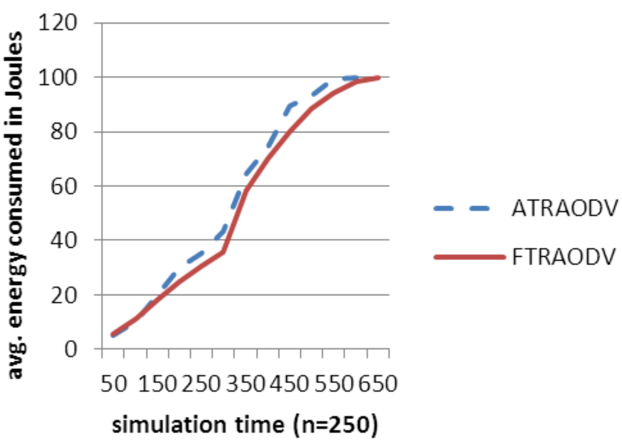

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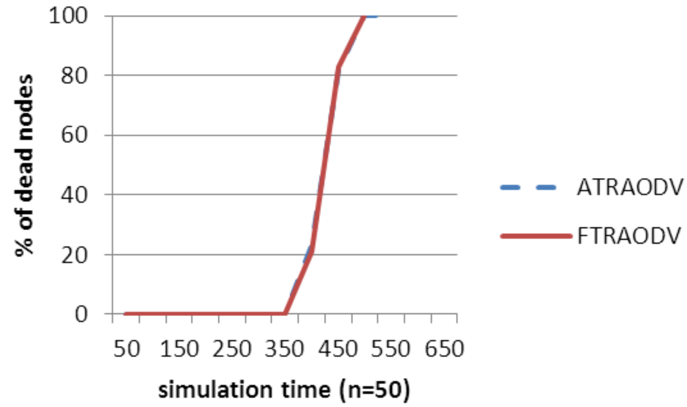
Figure. 3. Simulation Time vs. Avg. Energy Consumed in Joules

Thus as the node density increases, there is increase in the energy saving in the proposed FTRAODV protocol as compared to ATRAODV. From the Table II, considering network partitioning due to first node failure, it can be seen that ATRAODV is able to provide 18% to 20% more lifetime as compared to ATRAODV. Considering 50% node failure, FTRAODV is able to achieve 18% more network lifetime and considering 100% node failure, FTRAODV is able to provide around 9% more network lifetime as compared to ATRAODV.



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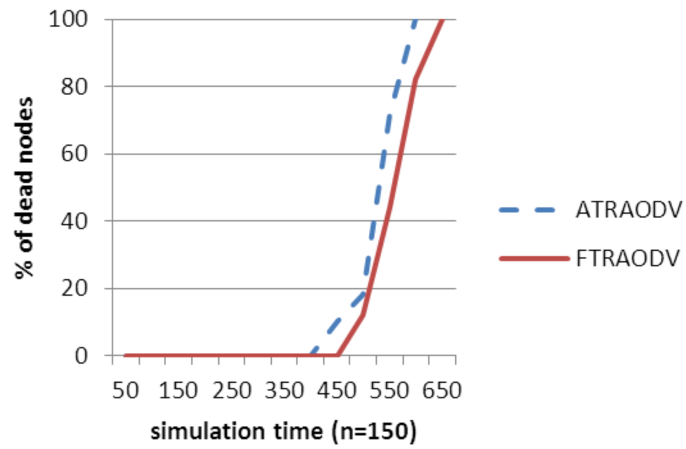

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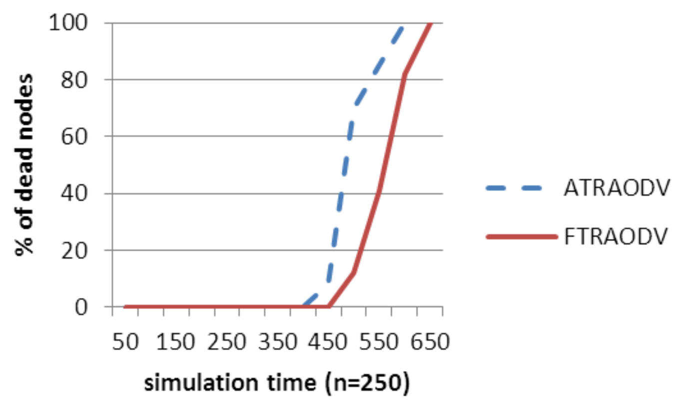

(c)

Figure. 4. Simulation Time vs. % of Dead Nodes

5. CONCLUSION

In this paper, a cross layer design of energy conservation protocol, based on fuzzy adaptive transmission power control at MAC layer depending on node density and a power aware routing based on fuzzy threshold energy at network layer, has been proposed. The proposed protocol, namely, FTRAODV, is able to achieve energy conservation and extend the network lifetime. The simulation experimental results are compared with ATRAODV routing protocol. It is observed that, in general, FTRAODV is able to extend network lifetime by 9% to 20% as compared to ATRAODV routing protocol. The proposed approach can also be applied to position based routing protocols also.

TABLE 2.

PERFORMANCE COMPARISON OF AODV,AFTE AND ATRAODV ROUTING PROTOCOLS FOR DIFFERENT NODE DENSITIES

No. of nodes	**Time when first node's residual energy becomes zero**		**Time when 50% of nodes' residual energy becomes zero**		**Time when 100% of nodes' residual energy becomes zero**	
	ATRAODV	**FTRAODV**	**ATRAODV**	**FTRAODV**	**ATRAODV**	**FTRAODV**
50	372	372	500	494	550	500
100	422	420	490	490	600	550
150	410	490	532	570	600	650
200	442	473	545	555	600	650
250	422	462	485	570	600	650
300	418	455	486	525	600	650

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